

Determining Safety Distance of Road Users at Unprotected Railway Level Crossing

(Case Study: Oro-Oro Ombo Wetan 1-2 Railway Level Crossings)

Nugroho Utomo¹, Ibnu Sholichin²

Civil Engineering Department

Universitas Pembangunan Nasional “Veteran” Jawa Timur, Surabaya, Indonesia

¹nugrohoutomo7577@gmail.com, ²ibnu.ts@upnjatim.ac.id

Abstract— Railway level crossing until now is still become the one of major accident cause for road users. Mainly caused by indiscipline acts of road users when pass a railway crossing such as opening an illegal crossing, trespassing closed crossing gate and unaware road users. In Province of East Java there are 165 railway level crossings at Surabaya – Malang railway line. Along that 165 numbers of railway level crossings which it protected by PT. Kereta Api Indonesia and other private corporations are 93 crossings and the rest of it are 67 crossings being unprotected and 5 are illegal crossings. Tendency of road users are trespassing protected and unprotected railway crossing. Government Act No. 13 clause 16 – 1992 about railroad system, declare that “In which caused intersection between railway and road that used for public or special traffic activities, road users must give priority to the train trips”. By the numbers of railway level crossings that has explained, it should be focused on unprotected railway level crossings which have a big probability for causing accidents than protected railway level crossings. From an intense survey obtained at least 2 unprotected railway level crossings which included to dangerous railway crossing categories, Oro-oro Ombo Wetan 1 and Oro-oro Ombo Wetan 2 in City of Bangil, District of Pasuruan. This research is proceeds to determine safety distance of road users and identify security facilities that must provide at unprotected railway crossing in City of Bangil, District of Pasuruan. By this research, the result of safety distance of road users that required on 3 unprotected railway level crossings and security facilities identifications can be used for safety transportations intends and the main reasons for future planning.

Keywords: *railway level crossings; safety distance for road users; security facilities at railway crossing; safety transportations.*

I. INTRODUCTION

Railway level crossings are amongst the most complex of road safety control systems, due to the conflicts between road vehicles and rail infrastructure, trains and train operations [1].

Railway level crossing until now is still become the one of major accident cause for road users. Mainly caused by indiscipline acts of road users when pass a railway crossing such as opening an illegal crossing, trespassing closed crossing gate and unaware road users. In the area that growing into an industrial and commercial area, the origins of road network that is local road type changed to collector road type. This roads transformation affected to appears of unprotected railway level crossings which existing railways and roads are closed to each other.

In Province of East Java there are 165 railway level crossings at Surabaya – Malang railway line. Along that 165 numbers of the railway level crossings which it protected by PT. Kereta Api Indonesia and other private corporations are 93 crossings and the rest of it are 67 crossings being unprotected and 5 are illegal crossings [2]. Tendency of road users are trespassing protected and unprotected railway level crossings. This behavior always makes an accident in railway level crossings are still going on. Most of road users assuming that existence of railway level crossings are interrupting their trips, so there is no need to give a priority for train trips. Government Act No. 13 clause 16 – 1992 about railroad system, declare that “In which caused intersection between railway and road that used for public or special traffic activities, road users must give priority to the train trips” [3].

By the numbers of railway level crossings that has explained, this research focused on unprotected railway level crossings which have a big probability for causing accidents than protected railway level crossings. From an intense survey obtained at least 3 unprotected railway level crossings which included to dangerous railway crossing categories, Oro-oro Ombo Wetan 1, Oro-oro Ombo Wetan 2 and Sukorejo in City of Bangil, District of Pasuruan.

This research is proceeds to determine safety distance of road users and identify security facilities that must provide at unprotected railway crossing in City of Bangil, District of Pasuruan.

By this research, the result of safety distance of road users that required on 2 unprotected railway level crossings and security facilities identifications can be used for safety transportations intends and the main reasons for future planning.

II. THEORITICAL REVIEW

A. Railway Level Crossing

According with Directorate General of Land Transportation Regulations No. SK.770/KA.401/DRJD/2005 about Guidance of Technical Design of Railway Level Crossing between Roads and Railways, railway level crossing is defined as level intersection or junction of railways and roads [4]. In fact, controlling of railway level crossing is very difficult which involving a vehicle traffic in one sides and train movements in another sides. Due with Government Act No. 23 – 2007 about railroads system arranged that:

1. Roads construction which designed intersecting with railway must be done in order to completing public needs and not harms the train trips
2. Railway level crossing constructions required a permission from railroads infrastructures owner
3. To gain safety of train and road users trip, illegal railway crossing must be closed by authorized government
4. On railway level crossing, road users must give priority to train trips [5].

Another code is also listed on Government Regulations No. 43 – 1993 [6] as an extension from Government Act No. 14 – 1992, clause 64 mentioning that on railway level crossing the road user must give priority to train trips [7]. This caused by characteristics of train. Train can't be stopped suddenly due to an object or barrier toward. Train needs a definite distance to braking before stops.

B. Types of Railway level crossing

The types of railway level crossings according with Design of Road Crossing with Railway Lines (Guide No.008/PW/2004) are listed below [8]:

1. Railway level crossings which equipped with automatic and non-automatic cross bar gate.
2. Railway crossing which not equipped with cross bar gate.

Railway level crossing equipped with cross bar whenever:

- a. The numbers of passing train on location are at least 25 trains/days and maximum 50 trains/days
- b. The numbers of average daily traffic 1000-1500 vehicle/days

Railway level crossing not equipped with cross bar gate whenever:

- a. The numbers of passing trains on location maximum 25 trains/days
- b. The numbers of average daily traffic 50 vehicle/days

Railway level crossing which equipped with cross bar gate must also equip with:

- a. Watch station with its facilities
- b. Light and strong cross bar that fit with requirements
- c. Chime with sound intensity 115dB at 1 meters distances
- d. List of warning codes
- e. Railway crossing officers on duty
- f. List of officers task on schedule
- g. List of train trips schedule that suitable with Grafik Perjalanan Kereta Api (GAPEKA) or Train Trips Graphics
- h. Warning code flag (red and green) and lamps

i. Another equipment like flashlights, First Aid Box
Railway level crossing which not equipped with cross bar gate must also equip with:

- a. Marking sign at roads before entering railway level crossings
- b. Rumble strips
- c. Warning sign
- d. Warning alarm
- e. Warning light

C. Railway level crossings conditions

On railway level crossings there are several conditions as mentioned below:

1. Railway level crossing not closed and unprotected, so: Surface of public roads must be made at same level with the surface of rail sleepers. Width of public roads at least 1 to 1.50 meters and only for pedestrian traffic
2. Railway level crossing not closed but protected, so:
 - a. Must be installed with railway warning sign
 - b. When train is going to pass, railway crossing officers give a red flag sign at day and red light at night to stops the traffic which are going to pass the railway crossing
3. Closed railway level crossing and unprotected:
 - a. Provides roads with 3 to 3.50 meters width
 - b. Cross bar operating with automatic and manual control
4. Closed railway level crossing and protected:
 - a. Available at roads with congested traffic and quite high frequency of train trips

D. Requirements of Railway level crossings

Road segments that can be designed to railway level crossings between roads and railways must have requirements as mentioned below [8]:

- a. Third degree class of roads
- b. 2/2-UD (2 lane/2 ways – Undivided) road types
- c. Not located at road curves which have radius at least 500 meters
- d. Level of gradients less than 5% from outer side of railways
- e. Fulfill clearance sights distance

E. Clearance sight distance

On railway level crossing, a proper clearance sight distance must be available for both sides of transportations operator (train and vehicle). Railway crossing with restricted lateral visibility should be more hazardous than sites with unrestricted visibility [9]. Visible zone on railway level crossings is a triangle forms which each distances obtained from train and vehicle design speed. If there are no signs which informs that train will pass, so according with Directorate General of Land Transportation No. SK.770/KA.401/DRJD/2005 about Guidance of Technical Design of Railway Level Crossing between Roads and Railways, arranged the clearance sight distance that depends on two conditions [10]:

a. Conditions when vehicle approaching railway crossing such that vehicle driver could see the train moving along to railway crossing as shown in figures 1 below:

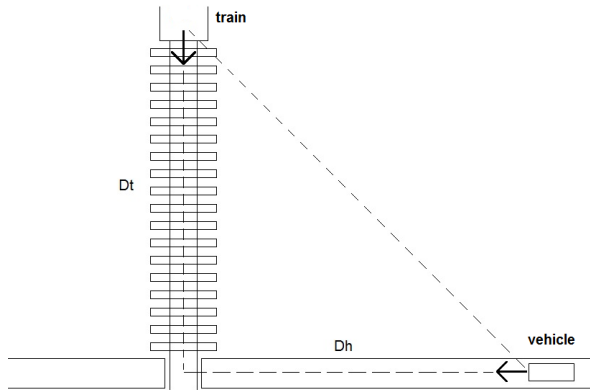


Fig.1: Conditions when vehicle approaching railway crossing such that vehicle driver could see the train moving along to railway crossing.

These conditions can be expressed by the formulas next:

$$D_h = 0.28 \cdot V_v \cdot t + \left(\frac{V_v^2}{254 \cdot f} \right) + D + d_e \quad (1)$$

$$D_t = \left(\frac{V_t}{V_v} \right) \cdot \left(0.28 \cdot V_v \cdot t + \left(\frac{V_v^2}{254 \cdot f} \right) + 2D + L + W \right) \quad (2)$$

With:

V_v = vehicle speed (km/h)

V_t = train speed (km/h)

t = driver response time (2.50 seconds)

f = braking coefficients, according with AASHTO:

$$f = -0.00065 \cdot V_v + 0.192$$

$$\text{for } V_v < 80 \text{ km/h}$$

$$f = -0.00125 \cdot V_v + 0.24$$

$$\text{for } V_v > 80 \text{ km/h}$$

D_h = clearance sight distance along the roads that enabling vehicle with speed V_v passing railway level crossings in moving train approaching to crossings conditions (m)

D_t = sight distance of moving train ahead to railway level crossings or sight distance toward railway (m)

D = distance between front overhang of vehicle with stopping line (4.50 m)

d_e = distance between drivers cabin with front overhang of vehicle (3.00 m)

L = length overall of vehicle (m)

W = distance between outer rail tracks, for single tracks taken 1.50 meters

These conditions and formulas prevail when there are no obstacles which have heights 1.00 meters or above at surrounding sights area of vehicle drivers toward railway level crossings. Angles between roads and railway should be arranged in 90° , and if not possible to make so it can be arranged bigger than 30° . If there are any obstacles appear at surrounding sights area of vehicle drivers toward railway level crossings, so conditions at point b is behave.

b. Conditions when vehicle stops in front of railway level crossings as shown in figures 2 below:

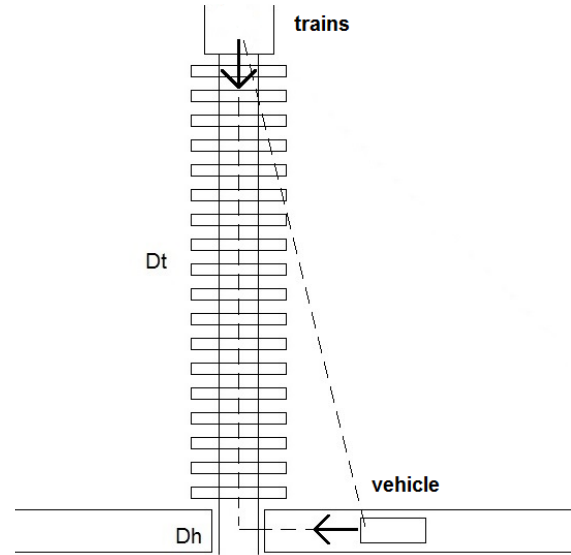


Fig.2: Conditions when vehicle stops in front of railway level crossings

These conditions can be expressed by the formulas next:

$$D_t = 0.28 \cdot V_t \left[\left(\frac{V_v}{a_1} \right) + \left(\frac{L+2D+W-d_e}{V_1} \right) + t \right] \quad (3)$$

With:

V_t = train speed (km/h)

V_1 = vehicle speed when going to pass railway crossing at gear 1 (taken 10 km/h)

a_1 = accelerations of vehicle when going to pass railway crossing at gear position 1 (0.45 m/sec^2)

D = distance between front overhang of vehicle with stopping line (4.50 m)

d_e = distance between drivers cabin with front overhang of vehicle (3.00 m)

L = length overall of vehicle (m)

W = distance between outer rail tracks, for single tracks taken 1.50 meters

t = driver response time (2.50 seconds)

III. RESEARCH METHODOLOGY

This research is takes several stages to obtain primary data from locations and brings to data analysis processing which results clearance sight distance requirements at railway level crossings.

A. Problem Identifications

Railway level crossing which especially unprotected conditions need to be analyzed from road users safety insurance aspects. These aspects are availability of clearance sight distance and existing conditions of railway crossing safety facilities. By this matters can be carried out to evaluate two locations of unprotected railway level crossing in City of Bangil, District of Pasuruan. Whether these three unprotected railway level crossings are still appropriate to serve daily traffic which passing or not.

B. Literature Studies

Literature studies are taking to find a reliable and relevance references which connecting with major theme of this research. These literatures accordance are from scientific journals, design and technical guidance, governments act and regulations and also textbook.

C. Data Collecting

Main data which used as raw materials for this research is primary data. Primary data is collecting directly from locations of studies.

The kinds of primary data are:

1. Speed of vehicle which passing railway level crossings
2. Speed of train which moving onto railway level crossings
3. Identification of safety railway level crossing facilities

Another data is secondary data. Secondary data is a data which used to completing analysis process, such as specifications of vehicle that passing at unprotected railway crossings (e.g.: length overall of the vehicle obtained from Geometrical Design of Inter-Urban Roads, Bina Marga Officials, Department of Civil Works 1997).

D. Data Analysis

Data analysis is carried out to determining clearance sight distance which required at unprotected railway crossings from primary data.

IV. DATA ANALYSIS

Data analysis is worked out according to specific locations of unprotected railway level crossings:

A. Oro-oro Ombo Wetan 1

Oro-oro Ombo Wetan 1 is located at eastern side from Bangil Railway Station which classified into local roads type. Primary data that can be achieved from these locations are:

1. Average vehicle speed when going to pass railway crossings : 37.54 km/h
2. Average train speed when approaching railway crossings : 88.67 km/h
3. There are no obstacles which have 1.00 meters or above heights that placed around visible zone, so analysis method can using conditions point a.

By data of average vehicle speed, braking coefficients (f) can be calculated:

$$\begin{aligned} V_v &= 37.54 \text{ km/h} \\ \text{for } V_v &\leq 80 \text{ km/h,} \\ f &= -0.00065 \cdot V_v + 0.192 \\ f &= -0.00065 \cdot 37.54 + 0.192 \\ f &= 0.167599 \\ f &\approx 0.17 \end{aligned}$$

t = driver response time (2.50 seconds)

D = distance between front overhang of vehicle with stopping line (4.50 m)

d_e = distance between drivers cabin with front overhang of vehicle (3.00 m)

Clearance sight distance can be calculated:

$$\begin{aligned} Dh &= 0.28 \cdot V_v \cdot t + \left(\frac{V_v^2}{254 \cdot f} \right) + D + d_e \\ Dh &= 0.28 \cdot 37.54 \cdot 2.50 + \left(\frac{37.54^2}{254 \cdot 0.17} \right) + 4.50 + 3.0 \\ Dh &= 66.41 \text{ m} \end{aligned}$$

So, clearance sight distance at Oro-oro Ombo Wetan 1 railway level crossing is 66.41 m

Then sight distance of moving train (Dt) when vehicle moving toward railway level crossings can be calculated:

L = length overall of vehicle
= 5.80 meters (from Geometrical Design of Inter-Urban Roads, Bina Marga Officials, Department of Civil Works 1997) [11]
D = distance between front overhang of vehicle with stopping line (4.50 m)
W = distance between outer rail tracks, for single tracks taken 1.50 meters

$$\begin{aligned} Dt &= \left(\frac{V_v}{V_v} \right) \cdot \left(0.28 \cdot V_v \cdot t + \left(\frac{V_v^2}{254 \cdot f} \right) + 2D + L + W \right) \\ Dt &= \left(\frac{88.67}{37.54} \right) \cdot \left(0.28 \cdot 37.54 \cdot 2.50 + \left(\frac{37.54^2}{254 \cdot 0.17} \right) + 2(4.50) + 5.80 + 1.50 \right) \\ Dt &= 177.658 \text{ m} \\ Dt &\approx 177.66 \text{ m} \end{aligned}$$

Sight distance of moving train (Dt) toward railway crossings at Oro-oro Ombo Wetan 1 railway level crossing is 66.41 m. By calculations of sight distance components at railway crossings which have proceed before, can be determined that approximately on 66.41 meters from railway level crossings vehicle must be ready to decrease the speed. By this distance, vehicle can be stopped safely in front of railway crossing stopping line. While from that distance, the moving train is reaching 177.66 m toward railway crossings. Identification of railway crossings safety facilities: Oro-oro Ombo Wetan 1 is unprotected railway crossings which noticed:

- a. Not equipped with watch station and cross bar gate
- b. Only equipped with railway crossings warning signs, warning lights and warning alarms

Existing conditions of Oro-oro Ombo Wetan 1 railway crossings shown as figure 3 next:



Fig.3: Existing conditions of Oro-oro Ombo Wetan 1 railway crossings

From figures 3 shown that Oro-oro Ombo Wetan1 railway crossings only equipped with railway crossings warning signs, warning lights and warning alarms. By Guidance of Technical Design of Railway Level Crossing between Roads and Railways explained that railway level crossing which not equipped with cross bar gate must also equip with marking sign at roads before entering railway level crossings and rumble strips. As advised Oro-oro Ombo Wetan 1 railway crossings safety facilities design must be followed as figure 4 below:

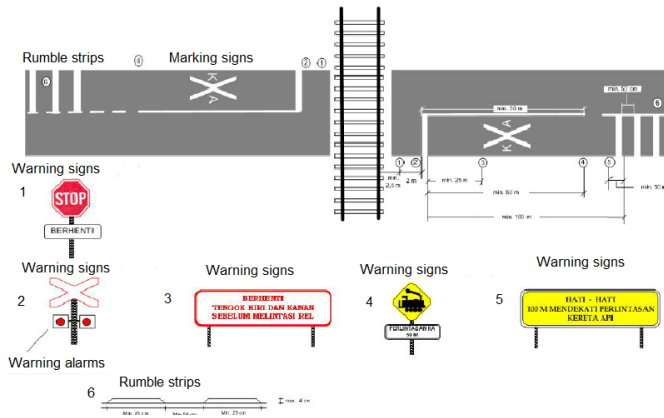


Fig.4: Safety facilities placement at Oro-oro Ombo Wetan 1 railway crossings that appropriate with Guidance of Technical Design of Railway Level Crossing between Roads and Railways

B. Oro-oro Ombo Wetan 2

Oro-oro Ombo Wetan 2 is located at eastern side from Oro-oro Ombo Wetan 1 which classified into local roads type. Primary data that can be achieved from these locations are:

1. Average vehicle speed when going to pass railway crossings : 18.47 km/h (5.13 m/s)
2. Average train speed when approaching railway crossings : 87.80 km/h
3. There are any obstacles which have 1.00 meters or above heights that placed around visible zone, so analysis method can using conditions point b.

Then distance of moving train (Dt) when vehicle moving toward railway level crossings can be calculated:

$$Dt = 0.28 \cdot V_t \left[\left(\frac{V_1}{a_1} \right) + \left(\frac{L+2D+W-d_e}{V_1} \right) + t \right]$$

With:

V_t = train speed (km/h)
= 87.80 km/h

V_1 = vehicle speed when going to pass railway crossing (m/s)

a_1 = accelerations of vehicle when going to pass railway crossing at gear position 1 (0.45 m/sec²)

D = distance between front overhang of vehicle with stopping line (4.50 m)

d_e = distance between drivers cabin with front overhang of vehicle (3.00 m)

L = length overall of vehicle (5.80 m)

W = distance between outer rail tracks, for single tracks taken 1.50 meters

t = driver response time (2.50 seconds)

$$Dt = 0.28 \cdot V_t \left[\left(\frac{V_1}{a_1} \right) + \left(\frac{L+2D+W-d_e}{V_1} \right) + t \right]$$

$$Dt = 0.28 \cdot 87.80 \left[\left(\frac{5.13}{0.45} \right) + \left(\frac{5.80+2(4.50)+1.50-3.0}{5.13} \right) + 2.50 \right]$$

$$Dt = 405.45 \text{ m}$$

By calculations of Dt, can be determined that distance of moving train when vehicle moving toward railway level crossings is approximately 405.45 m. Although the result of Dt calculation is showing distance of moving train quite far from railway crossings, but suggested for vehicle that going to pass railway crossings must stops immediately in front of stopping line because there are no clear visible zone around and for ensuring safety of transportations process. Identification of railway crossings safety facilities:

Oro-oro Ombo Wetan 2 is unprotected railway crossings which noticed:

- a. Not equipped with watch station and cross bar gate
- b. No proper visible zone placed around that enabling road users to make sure the trip safely
- c. Only equipped with railway crossings warning signs, warning lights and warning alarms

Existing conditions of Oro-oro Ombo Wetan 2 railway crossings shown as figure 5 next:



Fig.5: Existing conditions of Oro-oro Ombo Wetan 2 railway crossings

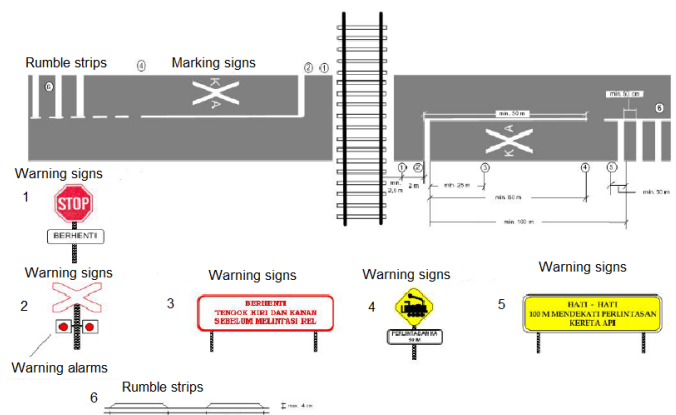


Fig.6: Safety facilities placement at Oro-oro Ombo Wetan 2 railway crossings that appropriate with Guidance of Technical Design of Railway Level Crossing between Roads and Railways

From figures 3 shown that Oro-oro Ombo Wetan 2 railway crossings only equipped with railway crossings warning signs, warning lights and warning alarms. By Guidance of Technical Design of Railway Level Crossing between Roads and Railways explained that railway level crossing which not equipped with cross bar gate must also equip with marking sign at roads before entering railway level crossings and rumble strips. As advised Oro-oro Ombo Wetan 2 railway crossings safety facilities design must be followed as figure 6 below:

V. CONCLUSION

By determining clearance sight distance which required on Oro-oro Ombo Wetan 1 railway level crossings with average train speed is 88.67 km/h, average vehicle speed when going to pass railway crossings is 37.54 km/h and clear visible zone is available. Obtained that approximately on 66.41 meters (Dh) from railway level crossings vehicle must be ready to decrease the speed. By this distance, vehicle can be stopped safely in front of railway crossing stopping line. While from that distance, the moving train is reaching 177.66 m (Dt) toward railway crossings. So, it needs to arrange speed limit of vehicle that will passing railway level crossing and adding safety facilities instruments such as road marking sign and rumble strips.

At Oro-oro Ombo Wetan 2, there is no clear visible zone available, average train speed is 87.80 km/h and average vehicle speed when going to pass railway crossings is 18.47 km/h. Obtained that distance of train toward railway crossing (Dt) is approximately 405.45 m. It means vehicle that going to passing railway crossing is still safe, but suggested for vehicle that going to pass railway crossings must stops immediately in

front of stopping line because there are no clear visible zone around and for ensuring safety of transportations process. Same adding actions to completing safety facilities instruments also applied at Oro-oro Ombo Wetan 2 railway level crossings.

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